Divided-attention task on driving simulator: comparison among three groups of drivers

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ABSTRACT

Introduction: Driving is a complex and dynamic task that requires performing simultaneously several sub-tasks, as traffic management and vehicle control. Driving involves both automatic and controlled processing depending on situation met and drivers' experience. **Method**: Three groups of drivers with different driving experience were submitted to a divided-attention task in order to assess the interference linked to a secondary task on driving behaviour. The main task was a car-following task and the secondary task was a number identification task which could appear on central or peripheral vision. **Results and discussion:** Results showed that driving performances increase with experience. Indeed, novice drivers, compared to more experienced drivers, took more time to brake and had more difficulties to maintain a stable position in the lane. This task allowed to differentiate driving behaviour depending on experience and could be used in training of novice drivers.

KEYWORDS

Secondary task; Simulator; Driving experience

INTRODUCTION

Many factors can negatively influence driver's skills and cause road accidents. Among them, the lack of experience is recognized as a main factor contributing to road accidents. Indeed, young drivers are widely overrepresented in road accidents so that, in France, it is the first cause of death among those under 25 years (Page, Ouimet & Cuny, 2004). Young drivers are particularly sensitive to distraction effect and have a higher risk of road accident linked to distraction (Hosking, Young & Regan, 2009). According to researchers, the lack of experience may be an additional reason that novice drivers are more easily distracted (Pradhan, Divekar, Masserang, Romoser, Zafian, Blomberg, Thomas, Reagan, Knodler, Pollatsek & Fisher 2011). Otherwise, attention is one of the most important factors and a primary cognitive requirement for safe driving. According to studies, attentional defaults are involved in about 22% to 50% of road accidents (Hendricks, Fells, & Freedman, 2001 ; Klauer, Dingus, Neale, Sudweeks, & Ramsey 2006 ; Lee, & Strayer, 2004 ; Van Elslande, Perez, Fouquet & Nachtergaele, 2005). Divided-attention is widely involved in driving activities which consist in various subtasks, each requiring an amount of attention. For example, drivers have to maintain a stable trajectory while being careful with traffic. Many studies using a driving simulator show that performing a secondary task deteriorates driving performances and increases reaction time (Andersen, Bian & Kang 2011 ; Atchley & Chan 2011 ; Bian, Kang & Andersen, 2010 ; Brookhuis & De Waard, 1994 ;; Horberry, Anderson, Regan, Triggs & Brown, 2006 ; Hosking & al, 2009 ; Lamble, Kauranen, Laakso & Summala, 1999). For example, using a mobile phone during a car following task increases the time-to-collision , the response time to brake (Lamble & al,1999) and delays the reaction time to headway changes (Brookhuis & De Waard, 1994). Driver's distraction by visual secondary task leads to an increase of mistake production (Young, Salmon, & Cornelissen, 2012). This deterioration of performance linked to an additional task is confirmed by a study carried out on real-environment (Blanco, Biever, Gallagher & Dingus, 2006). When drivers perform simultaneously several tasks, they are placed in a divided attention situation. The secondary task draws the driver's attention away from the driving task and the driver has to divide its cognitive resources between driving and the secondary task. Studies linked to driver's distraction by an additional task were the object of experiments related to phone and assistance device and experiments on ocular movements. It seems to be very interesting to complete these works with an approach in terms of attention resources.

Rasmussen (1979) considers the loss of control within a complex system as the results of inadequate adaptation between operator's knowledge and environments constraints. Three behaviour levels are distinguished : 1. Skill based behaviour where the risk is related to routine errors, inattention errors. This level involves majoritarily automatic processing which requiere few attentional resources ; 2. Rule-based behaviour which is activated if it is required by the situation. At this level, the risk is the activation of rules which are maladjusted to the situation ; 3. Knowledge based behaviour, in the case where no rules allow to solve the problem. The operator have to improvisate and find a solution based on anterior knowledge. The risk is not to find the solution. This level involves controlled processing which requiere a lot of attentional resources. This model is suitable to explain differences between novice and experienced drivers. Indeed, experienced drivers use majoritarily skill-based behaviour, while novice drivers, whose behaviours are not totally automatized, use a knowledge-based behaviour.

The aim of this research is to assess the interference linked to a secondary task while driving and investigate if this interference vary as function of driving experience.

METHOD

Participants

Thirty-seven volunteers, divided up into three groups, participated in the study. The first group was consisted in 13 novices drivers aged 18 and had their license for less than 4 months. The second group was made up of 12 young drivers more experienced, i.e. with 36 months of driving license and aged 21. The third group was composed of 12 drivers more aged and experienced, i.e. with at least 8 years of driving license. All experienced drivers had their own vehicle and traveled over 20,000 km.

Simulator

The driving study was carried out on the SIM^2-IFSTTAR fixed-base driving simulator equipped with an ARCHISIM object database (Espié, Gauriat & Duraz, 2005). The driving station comprised one quarter of a vehicle. The image projection (30Hz) surface filled an angular opening that spans 150° horizontally and 40° vertically. The vehicle had an automatic gearbox and was not equipped with rearview mirrors.

Procedure & Statistical analyses

Participants performed training before the beginning of the experiment. The main task consisted in following a vehicle while keeping a constant distance with this vehicle. The lead vehicle speed varied with sixteen accelerations and sixteen decelerations either with high or low amplitude. The driver was placed in the middle of three-lane road, in a way that the environment was perfectly symmetric. The secondary task consisted in the number identification, even or odd. A three digit number appeared each 1.5 seconds to 2.5 seconds during 400 milliseconds on a central or peripheral visual field. Participants had to activate the right control of the steering wheel if the target was even or the left control if the target was odd. In the first time, in order to obtain a reference measure of driving performance, volunteers performed a car-following task alone. The secondary task was also performed alone in order to ensure that it lead to a similar cost for novice and experienced drivers. The order of presentation of these two simple tasks was counterbalanced during the experiment. In the second time, drivers had to perform simultaneously a car following task and an identification task of the number parity. The interference related to the secondary task was computed and compared with reference measures.
The choice of this divided-attention task seems relevant because the main task of car-following become automatic with experience, while it requires controlled processing for novice drivers. This main task allows involving different cognitive processing depending on driving experience. For experienced drivers, attentionnal resources liberated by the main task automation could be reinvested in the secondary task of number identification. Our procedure allows us to ensure that the secondary task involves controlled processing for all drivers.
The dependent variables were divided into four categories: 1. Speed: index of speed regulation (time taken by drivers to reach the same speed of the lead vehicle) and reaction time to press on the brake; 2. Distance: mean and standard deviation of inter-vehicular distance; 3. Position in the traffic lane: mean and standard deviation of lane position (SDLP). Performance on the secondary task: reaction time and accuracy (percentage of correct, incorrect responses and omissions). The independent variables were driving experience (three groups) and task (single vs dual). Statistical analyses were performed using Statistica. The data was tested for significance using repeated measures analysis of variance ($p \leq 0.05$). Results from the reference task and the additional task were compared. Bonferroni's test was applied to verify the significance threshold.

RESULTS

Only significant results are presented in this paper. ANOVA revealed a significant main effect of the task attentionnal requirement. The analyses highlighted an impairment of performance in dual task compared to the car-following single task on the time necessary to reach the same speed that the lead vehicle and on the mean inter-vehicular distance. In dual-task, the percentage of correct responses decreased and the percentage of omissions increased compared to those in single-task (See Table 1).

Table 1. Performances depending on task (single vs. dual)

Dependant variable	Single-task	Dual-task	F
Index of speed regulation (sec)	m= 11.04 (sd= 1.66)	m= 10.34 (sd= 2.24)	$F(1,31) = 8.85$, $p \leq 0.005$
DIV mean (m)	m= 54.92 (sd= 14.37)	m= 50.08 (sd= 8.57)	$F(1,31) = 4.61$, $p \leq 0.05$
Response correct (%)	m= 87 (sd = 0.11)	m= 91.2 (sd= 0.07)	$F(1,31) = 24.87$, $p \leq 0.001$

Omission (%)	m= 2.9 (sd = 0.04)	m= 6.1 (sd= 0.1)	F(1,31) = 13.27, p ≤ 0.001

An interaction between task and number's location (central vs peripheral) on the response accuracy (correct responses F(1,31) = 12.77 , p <0.005 and omissions F(1,31) = 11.33, p < 0.005) showed that these impairments in dual task occurred only when the numbers appeared in peripheral vision (See Figure 1 & 2).

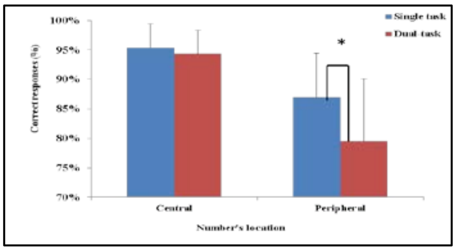

Figure 1. Correct responses' percentage depending on task (single vs. dual) and number's location (central vs. peripheral)

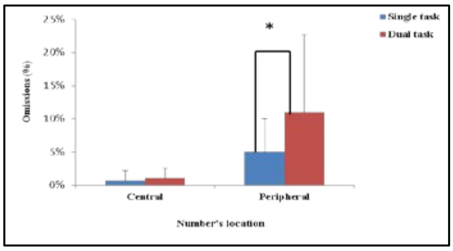

Figure 2. Omissions' percentage depending on task (single vs. dual) and number's location (central vs. peripheral)

ANOVA also revealed a significant decrease of time to brake (F(2,31) = 4.8, p ≤ 0.05) and of standard deviation of lateral position (SDLP) (F(2,31) = 8.22, p ≤ 0.005) with driving experience. Conversely, the percentage of correct responses (F(2,31) = 4.91, p ≤ 0.05) increased with driving experience (See Table 2).

Table 2. Performances depending on driving experience

Dependant variable	Novice	Experienced (36 months)	Experienced (8 years)	F
Time to brake (sec)	m= 12.39 (sd= 3.12)	m= 10.45 (sd= 3.73)	m= 8.55 (sd= 3.67)	F(2,31) = 4.80 , p ≤ 0.05
SDLP (m)	m= 62.82 (sd= 10.72)	m= 55.65 (sd= 15.55)	m= 45.78 (sd= 92.99)	F(2,31) = 8.22 , p ≤ 0.005
Response correct (%)	m= 86.2 (sd = 11.2)	m= 90 (sd= 8.4)	m= 91.4 (sd= 7.6)	F(2,31) = 4.91 , p ≤ 0.05

DISCUSSION

The aim of the present research was to explore the divided-attention abilities of young novice drivers compared to experienced drivers, and to determine whether young novice drivers were particularly affected by the interference linked to secondary task.

Globally, compared to a single-task, a divided-attention task affects negatively both driving performance and identification abilities on the secondary task. These results are congruent with the literature concerning a dual-task. Performing two tasks simultaneously causes an impairment of performance compared to the realization of each task separately. In accordance with the limited capacity theory of attention (Kahneman, 1973) performing a divided-attention task causes an increase of mental workload and task demands can exceed driver's attentional resources.

Interaction effects between number's locations and performances indicate that impairment linked to the secondary task occurs only when numbers appear in peripheral vision. Results are consistent with eye-movement's studies while driving which indicate that when situation complexity increases, drivers focus their glances on central vision.

Globally, novice drivers brake later than experienced drivers with 36 months or 8 years of driving experience. The skills necessary to rapidly brake would be therefore acquired from 36 months of driving. Otherwise, novices and experienced from 36 months, had higher SDLP than drivers with 8 years of driving license. As SDLP reflects the skills of lane-keeping, these later don't seem completely acquired even after 36 months of driving license. Finally, novice drivers' percentage of correct responses is fewer than experienced ones, which is directly linked to driving inexperience. Results are interpreted in terms of an amount of available resources which is different depending on driving experience. Indeed, the main task (car-following) is not automatic yet for this group of drivers, and thus requires knowledge-based behaviour and many cognitive resources. Performing a secondary task has thus for consequence a mental overload and an inadequate resource distribution. For novice drivers, attentional resources are highly mobilized by sensori-motor sub-tasks to the detriment of cognitive sub-tasks. These outcomes are consistent with previous studies on distraction among young novice drivers (Stutts, Reinfurt, Staplin & Rodgman, 2001 ; Metz, Schömig & Krüger, 2011).

Moreover, the divided-attention task is a relevant choice because, conversely to a single-task, it allows experienced drivers with 36 months of driving to be distinguished of those who have 8 years of experience. It shows that even with 36 months of practice, all resources necessary to safe driving are not available.

To sum up, experienced drivers thus have better adaptation abilities and/or greater motor skills than novice drivers, and meaning that acquisition of such capacities is progressive. Novice drivers training in simulator could have benefits on driving behaviour from the first month of driving.

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